Improving Team Cognitive Readiness through the Multi-Agent System for Targeting Team Mental Models (MAST-TMM)

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Programmatics

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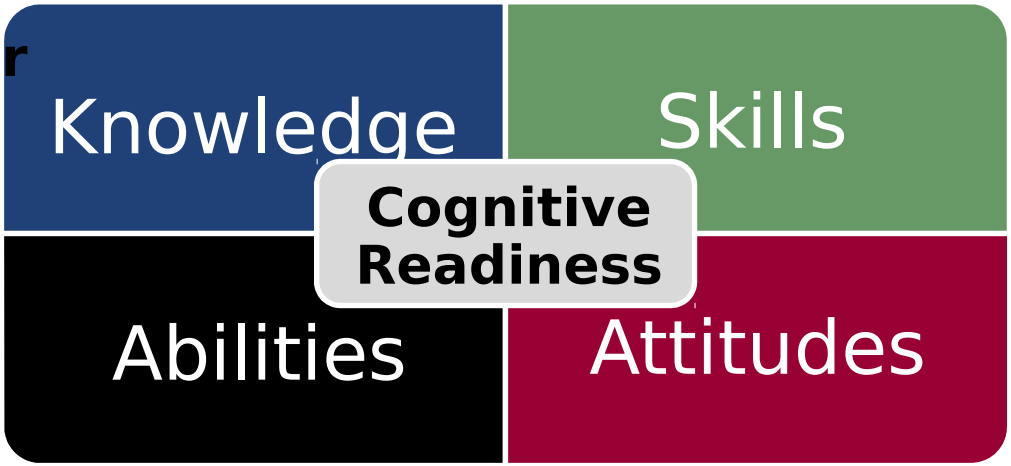
What is Cognitive Readiness?

- A scientific, theoretically-derived construct that is highly related to decision-making and performance
- Defined as being mentally prepared for whatever situation arises
- Multi-faceted construct that, like SA and other cognitive constructs, has strong probabilistic relationships with per
- Provides potential for improved mission effectiveness when appropriately matched with task/mission demands



Project Overview

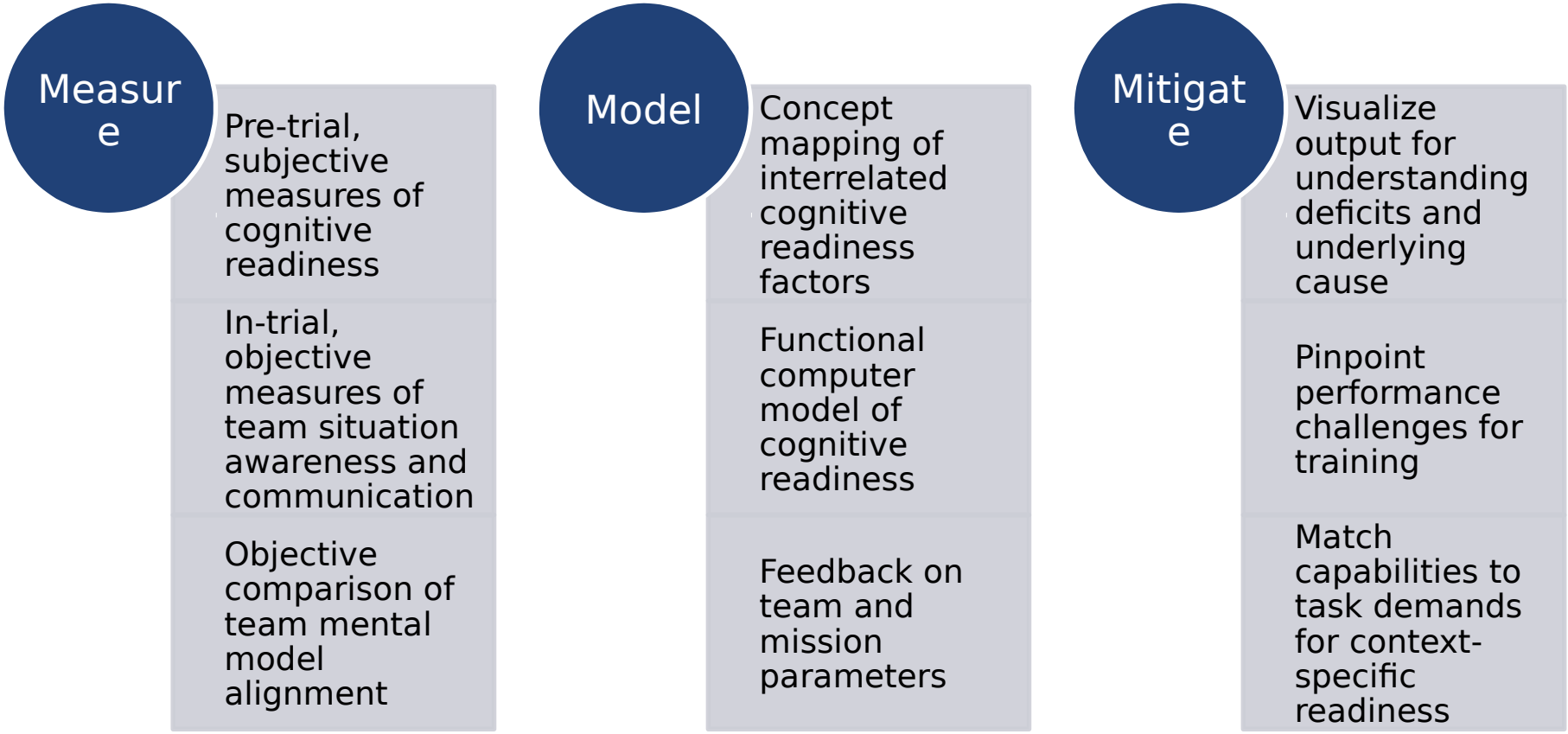
- **Objective**
  - **Develop an automated team performance measurement and modeling tool that can predict team performance based on task requirements**
  - **Currently few measures of cognitive readiness**
    - **Rely on subjective data**

Project Overview

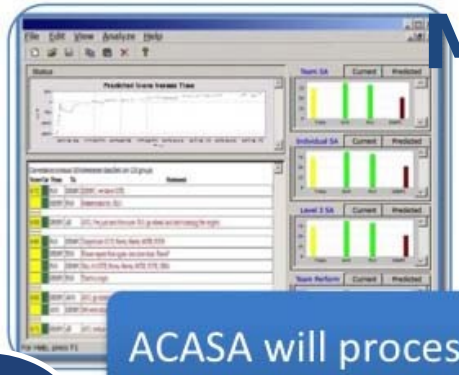
- **Why are we doing this?**
  - **Evaluate team performance across a variety of mission parameters**
  - **Identify and address team performance deficits**
  - **Evaluate system effectiveness**
  - **Develop effective, high-performing teams**
  - **Better target training based on individual and team needs**
  - **Predictive capability for examining potential mission challenges**

Project Overview

- **Approach**

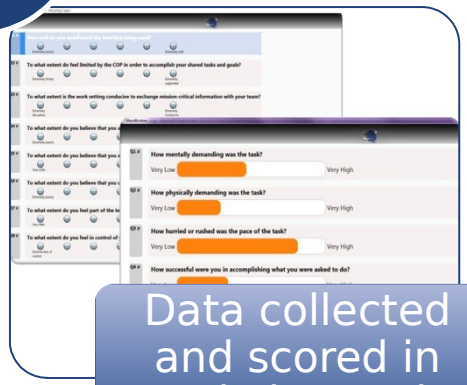

Measure
Pre-trial, subjective measures of cognitive readiness
In-trial, objective measures of team situation awareness and communication
Objective comparison of team mental model alignment
Model
Concept mapping of interrelated cognitive readiness factors
Functional computer model of cognitive readiness
Feedback on team and mission parameters
Mitigate
Visualize output for understanding deficits and underlying cause
Pinpoint performance challenges for training
Match capabilities to task demands for context-specific readiness

MAST-TMM Concept



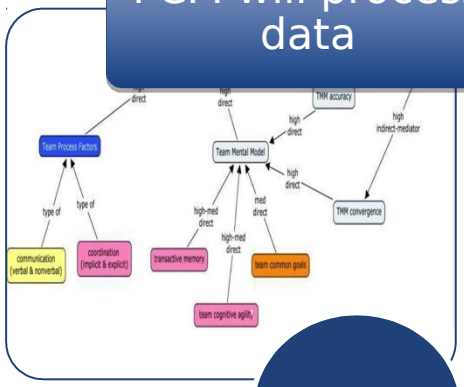
ACASA will process communications

Measure



Data collected and scored in existing tool (SEAS)

FCM will process data



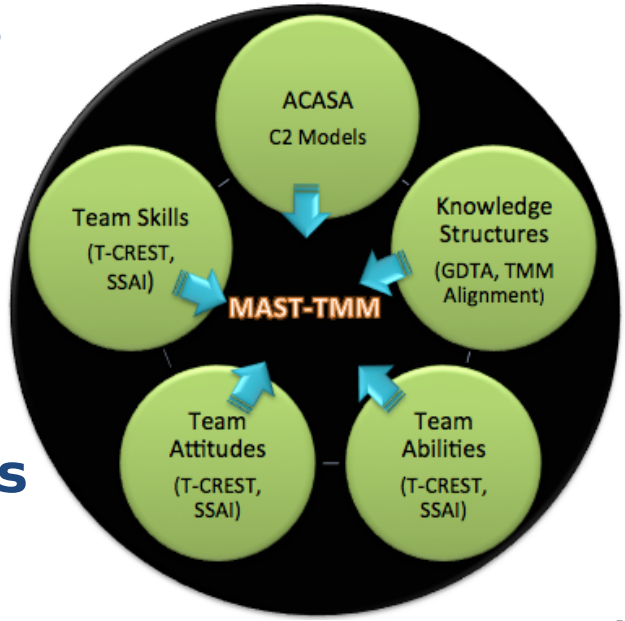
Model

Mitigate

SEAS will take FCM outputs for visualization

MAST Measures

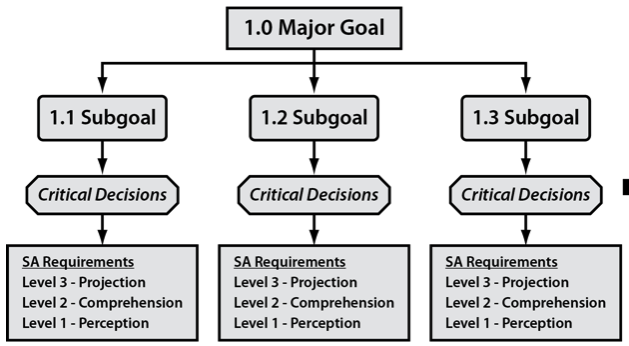
- **Pre Trial**
  - **MAST psychometric instrument**
    - **Aspects of cognitive readiness**
    - **Aspects of shared SA**
- **During Trial**
  - **Situation Awareness (SA) Queries**
    - **Evaluate own state of knowledge**
  - **SA Alignment Queries**
    - **Assess state of knowledge about teammates**
  - **Automated Communication of Situation Awareness (ACASA)**
    - **Evaluate SA and SA Alignment from technology-mediated, natural team communications**



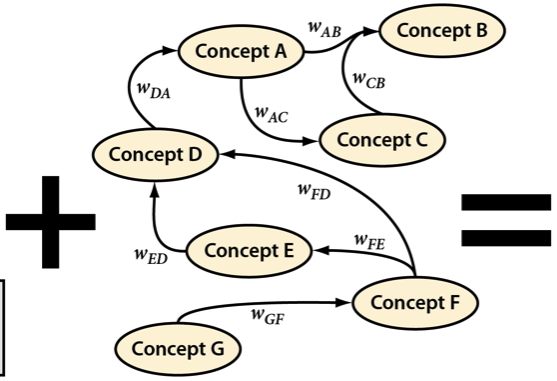
Goal is for MAST to use either query data or communication data

MAST Modeling Using SA FCM

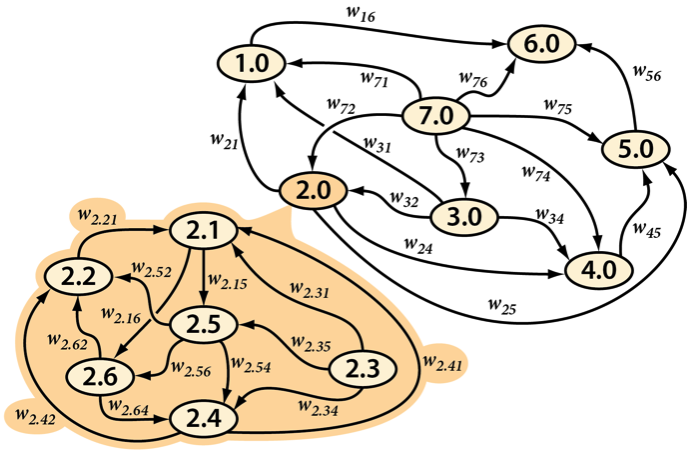
- Combines fuzzy logic and concept mapping
- Uses GDTA for SA elements
- Creates concept map
  - Weights
  - Relationships
- Model "messy" relationships
  - Qualitative
  - Subjective
  - Inexact



Goal-Directed Task Analysis (GDTA)



Fuzzy Cognitive Maps (FCMs)

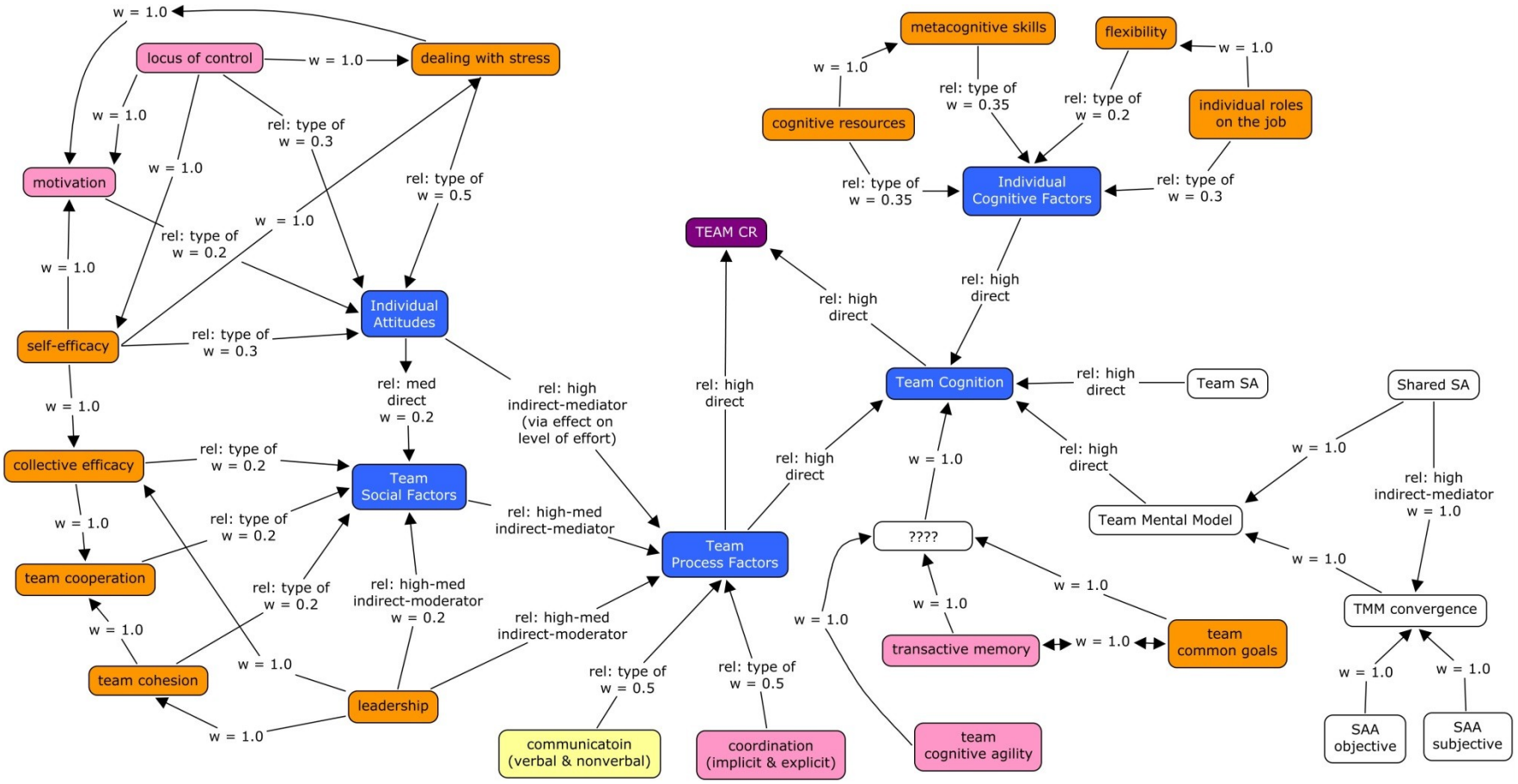


SA-FCM Model

MAST-TMM Progress

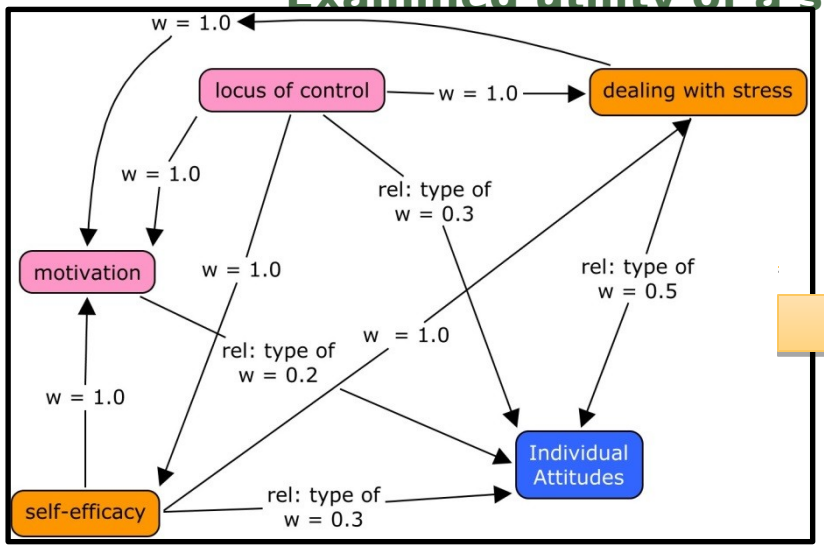
- **MAST-TMM Cognitive Map**
  - **Theoretical conceptualization of cognitive readiness**
    - **Five high level concept nodes – Individual Attitudes, Team Social Factors, Team Process Factors, Team Cognition, Individual Cognitive Factors**
    - **Twenty-five lower level concept nodes**
  - **Multiple interrelationships among nodes defined along with initial weights**
    - **SME input**
    - **Extant literature**
  - **Mapped directly to MAST-TMM measures**

MAST Cognitive Modeling



MAST-TMM Cognitive model

- **Developed preliminary matrix models for five high level concept nodes**
  - **Static model to test fuzzy mathematical approaches**
    - **Examined utility of integration of matrices (i.e., concept outputs from one matrix "activates" or "contributes" to concept activation in another matrix)**
    - **Examined utility of a single, large integrated matrix**



WEIGHTS	Efficacy	Motivation	Locus of Control	Stress	Indiv Attitudes
Efficacy	0	1	0	1	0.3
Motivation	0	0	0	0	0.2
Locus of Control	1	1	0	1	0.3
Stress	0	1	0	0	0.5
Indiv Attitudes	0	0	0	0	0
Start (Squashed)	1	0	0	0	0
matrix math	0	1	0	1	0.3
squash function	0.5	0.731058446	0.5	0.731058446	0.574442467
matrix math	0.5	1.731058446	0	1	0.811740912
squash function	0.622459252	0.849547608	0.5	0.731058446	0.692480242
matrix math	0.5	1.853517699	0	1.122459252	0.87217652
squash function	0.622459252	0.864539446	0.5	0.754444458	0.705198263
matrix math	0.5	1.87690371	0	1.122459252	0.886867894
squash function	0.622459252	0.86725493	0.5	0.754444458	0.70824327
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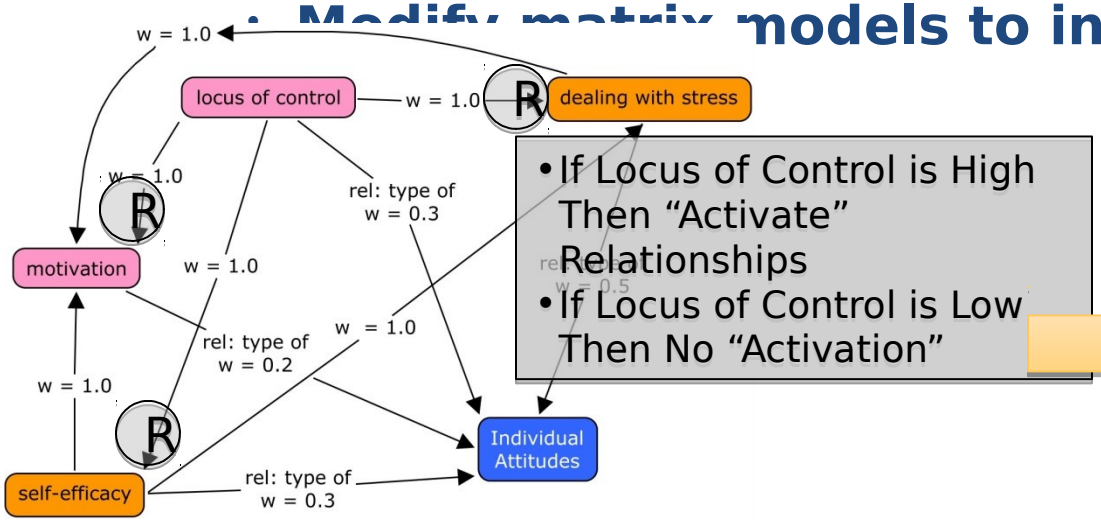
matrix math	0.5	1.87690371	0	1.122459252	0.88741099
Convergence	0.622459252	0.86725493	0.5	0.754444458	0.70835548

MAST-TMM Progress

- **Examine need to incorporate rule-based components to model**
  - **Control activations of highly qualitative concepts that may not be best represented with mathematical formulation alone**
  - **Modify matrix models to integration of rules**



- If Locus of Control is High Then "Activate" Relationships
- If Locus of Control is Low Then No "Activation"

WEIGHTS	Efficacy	Motivation	Locus of Control	Stress	Indiv Attitudes
Efficacy	0	1	0	1	0.3
Motivation	0	0	0	0	0.2
Locus of Control	1	1	0	1	0.3
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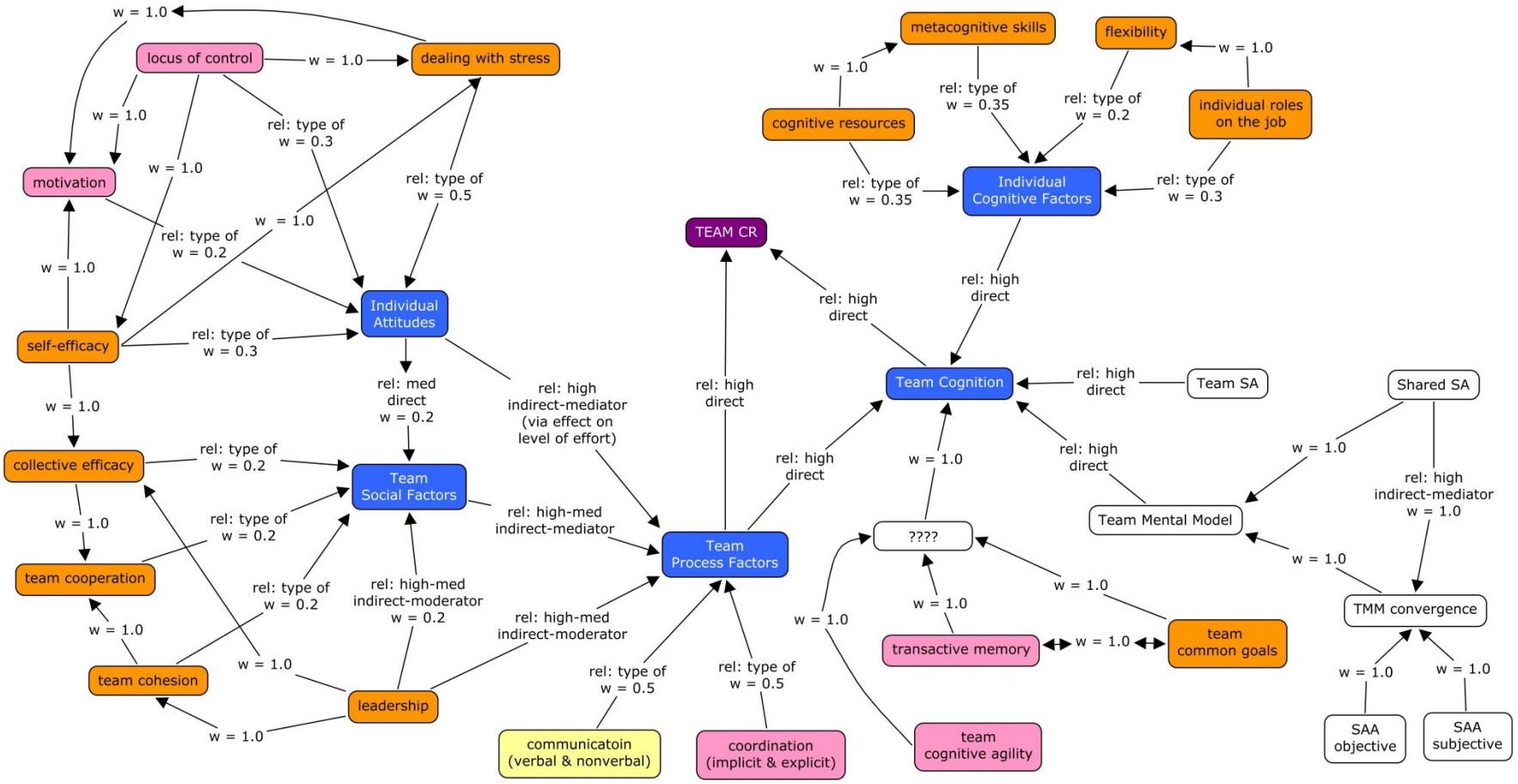
MAST-TMM Concept Map



MAST-TMM Measurement

Metric	Reverse	SurveyItem	Cognitive Readiness Metric
SMI	FALSE	When new information comes in, I consider how it relates to what I already know.	Cognitive Agility
SMI	FALSE	I use multiple thinking techniques or strategies to solve the problems I encounter.	Cognitive Agility
SMI	FALSE	As I am solving a problem, I consider the best strategies and techniques for problem solving.	Metacognition
SMI	FALSE	I consider which thinking technique or strategy is best to solve a particular problem.	Metacognition
CCAI	FALSE	I can laugh at myself when I make a mistake.	Dealing with Stress
CCAI	FALSE		
PSI	TRUE	When my first efforts to solve a problem fail, I lose confidence in my ability to handle the situation.	Cognitive Resources
PSI	TRUE	Sometimes I get so overwhelmed by a complex problem that I am unable to consider different approaches for dealing with it.	Cognitive Resources
SA Tech	FALSE	I work effectively with people who are different from me.	Flexibility/Openess
SA Tech	FALSE	I enjoy working with people who think differently than I do and bring a different perspective to the problem.	Flexibility/Openess

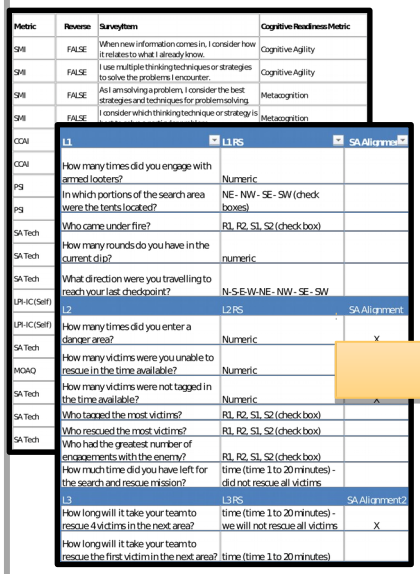
Subjective CR Assessment

L1	L1 RS	SA Alignment
How many times did you engage with armed looters?	Numeric	
In which portions of the search area were the tents located?	NE - NW - SE - SW (check boxes)	
Who came under fire?	R1, R2, S1, S2 (check box)	
How many rounds do you have in the current clip?	numeric	
What direction were you travelling to reach your last checkpoint?	N-S-E-W-NE - NW - SE - SW	
L2	**L2 RS**	**SA Alignment**
How many times did you enter a danger area?	Numeric	X
How m... rescue...		
How m... the tin...		
Who ta...		
Who rescued the most victims?	R1, R2, S1, S2 (check box)	
Who had the greatest number of engagements with the enemy?	R1, R2, S1, S2 (check box)	
How much time did you have left for the search and rescue mission?	time (time 1 to 20 minutes) - did not rescue all victims	
L3	**L3 RS**	**SA Alignment2**
How long will it take your team to rescue 4 victims in the next area?	time (time 1 to 20 minutes) - we will not rescue all victims	X
How long will it take your team to rescue the first victim in the next area?	time (time 1 to 20 minutes)	

Objective SA Assessment

MAST-TMM UI Design

- **Modify existing SEAS toolset for MAST administration**


Metric
Reverse
SurveyItem
Cognitive Readiness Metric
SMI
FALSE
When new information comes in, I consider how it relates to what I already know.
Cognitive Agility
SMI
FALSE
I use multiple thinking techniques or strategies to solve the problems I encounter.
Cognitive Agility
SMI
FALSE
As I am solving a problem, I consider the best strategies and techniques for problem solving.
Metacognition
SMI
FALSE
I consider which thinking technique or strategy is
Metacognition
CDAI
CDAI
PSI
PSI
SA Tech
SA Tech
SA Tech
LPI-IC(Self)
LPI-IC(Self)
SA Tech
MOAQ
SA Tech
SA Tech
SA Tech
L1
L1RS
SA Alignment
How many times did you engage with armed looters?
Numeric
In which portions of the search area were the tents located?
NE - NW - SE - SW (check boxes)
Who came under fire?
R1, R2, S1, S2 (check box)
How many rounds do you have in the current clip?
numeric
What direction were you travelling to reach your last checkpoint?
N-S-E-W-NE - NW - SE - SW
L2
L2RS
SA Alignment
How many times did you enter a danger area?
Numeric
X
How many victims were you unable to rescue in the time available?
Numeric
How many victims were not tagged in the time available?
Numeric
X
Who tagged the most victims?
R1, R2, S1, S2 (check box)
Who rescued the most victims?
R1, R2, S1, S2 (check box)
Who had the greatest number of engagements with the enemy?
R1, R2, S1, S2 (check box)
How much time did you have left for the search and rescue mission?
time (time 1 to 20 minutes) - did not rescue all victims
L3
L3RS
SA Alignment2
How long will it take your team to rescue 4 victims in the next area?
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X
How long will it take your team to rescue the first victim in the next area?
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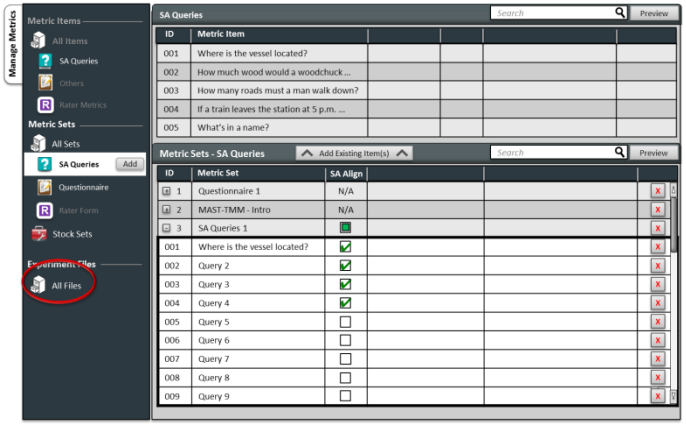
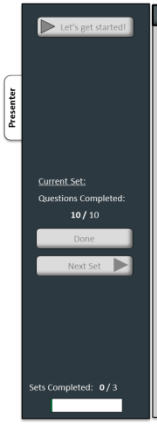
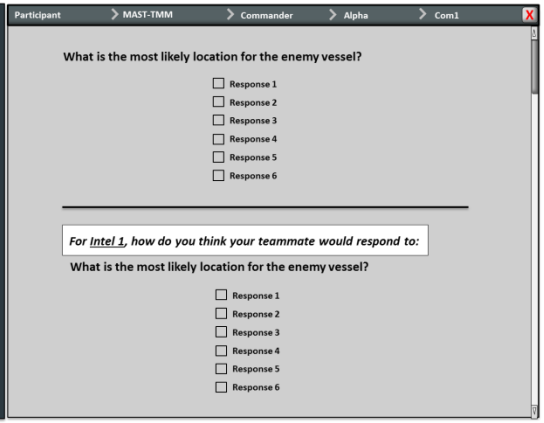




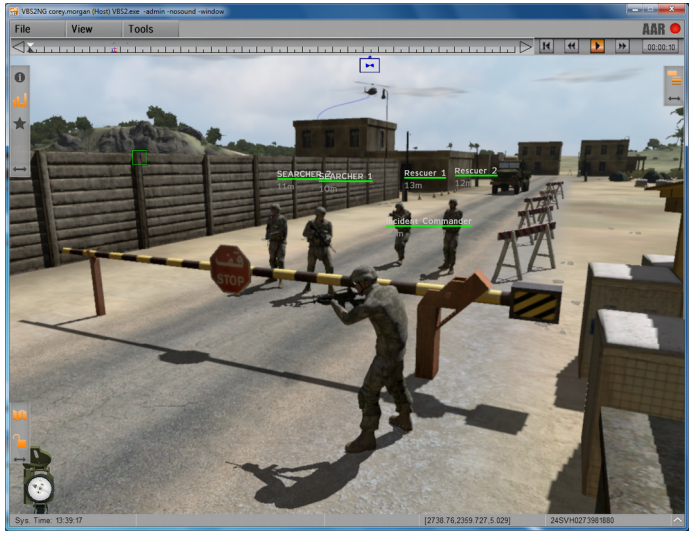


MAST-TMM Output UI Design

MAST-TMM Output UI Design

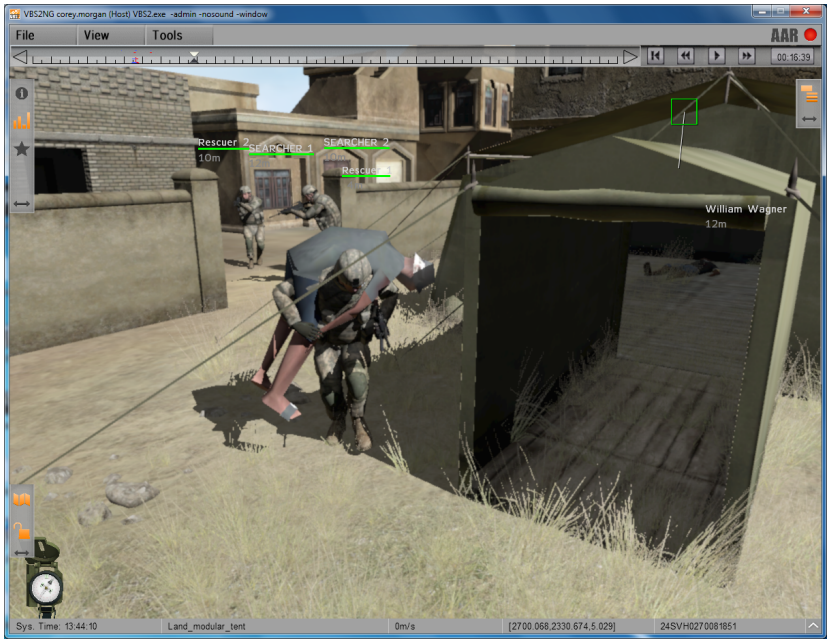
Data Collection

- **Data collection at UTA (ROTC) and USMA (Cadets)**
  - **VBS2 game-based test bed**
  - **Military search and rescue mission with potential enemy engagement**
  - **Two- or four-person teams with distinct roles/tasks**
    - **Searchers navigate environment to locate casualties**
    - **Rescuers coordinate for evacuation of casualties**



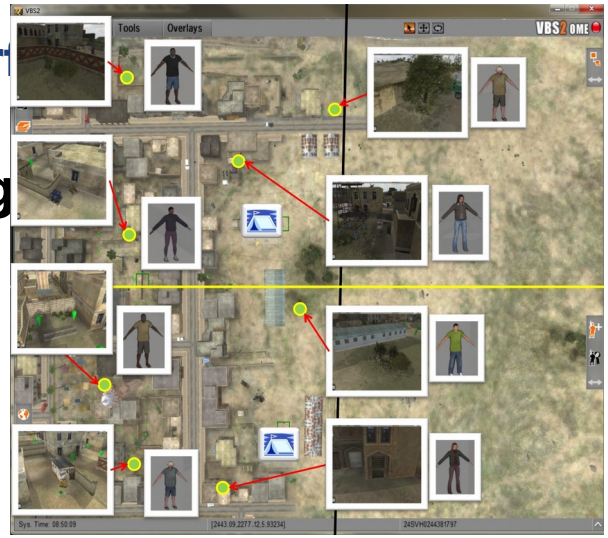
Data Collection

- **Continued**
  - **Conditions**
    - **Low/High “Noise” (environmental stressors)**
    - **Low/High task difficulty (number of victims, 4 or 8)**
  - **Measures:**
    - **Subjective CR Factors**
    - **Objective SA**
    - **SA Alignment**
    - **Objective Performance**
    - **Comms Audio**
    - **Subjective Team Workload**
    - **Subjective SA**



Study Status

- **70+ participants completed at UTA**
  - Some may be excluded due to 3 person teams rather than 4
- **Hypotheses**
  - Teams with higher model scores will perform better on the tasks
  - Different factors will predict high per navigation and rescue tasks
  - Performance metrics
- **Data scoring and analysis is ongoing**
  - SA metrics
  - Communications Data
    - Currently analyzing communications from prior, related study to tune semantic model
- **Stay tuned for results!**



Conclusions

- **MAST is an ambitious tool designed to measure team characteristics, analyze the output through a cognitive modeling tool, and predict team performance based on task characteristics**
- **Data collection and analysis is ongoing**
- **Communication analysis will be evaluated post hoc to determine the feasibility of replacing some or all of the current measures with communications measures**

Questions?